NExT Forum on AI and Next-Generation Communication

Embedding AI in Communication Systems

Yu-Chee Tseng
Chair Professor
National Yang Ming Chiao Tung University

A Speech of
MoE National Chair
Professorship
(教育部國家講座)

About the Speaker

Research Interests

- Internet of Things
- AI and Smart Sensing
- AI and Smart Networking
- AI and Smart Vision

Current Positions

- Chair Professor, NYCU (陽明交通大學/講座教授)
- Director, Pervasive AI Labs, MOST (科技部/人工智慧普適研究中心/主任)
- Founding Dean, College of Artificial Intelligence (陽明交通大學/智慧科學院/院長)

Outline

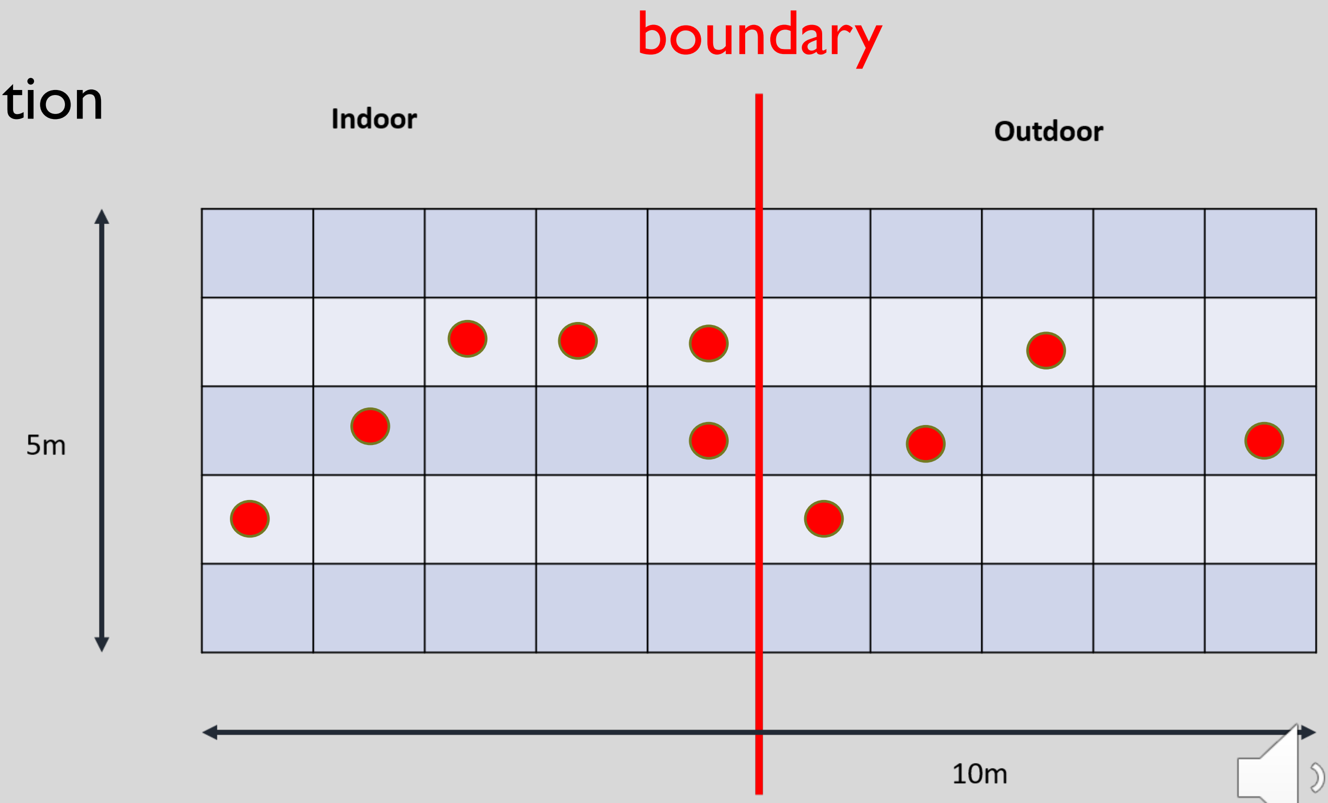
1. Wireless "Boundary" Localization
2. "Instant Alerts" for Accurate Messaging in 5G

Part 1:
A multi-task LSTM model for construction boundary positioning

Yu-Ting, Liu, J.-J. Chen, Y.-C. Tseng, and F. Li
ICCCN 2021

Main Idea

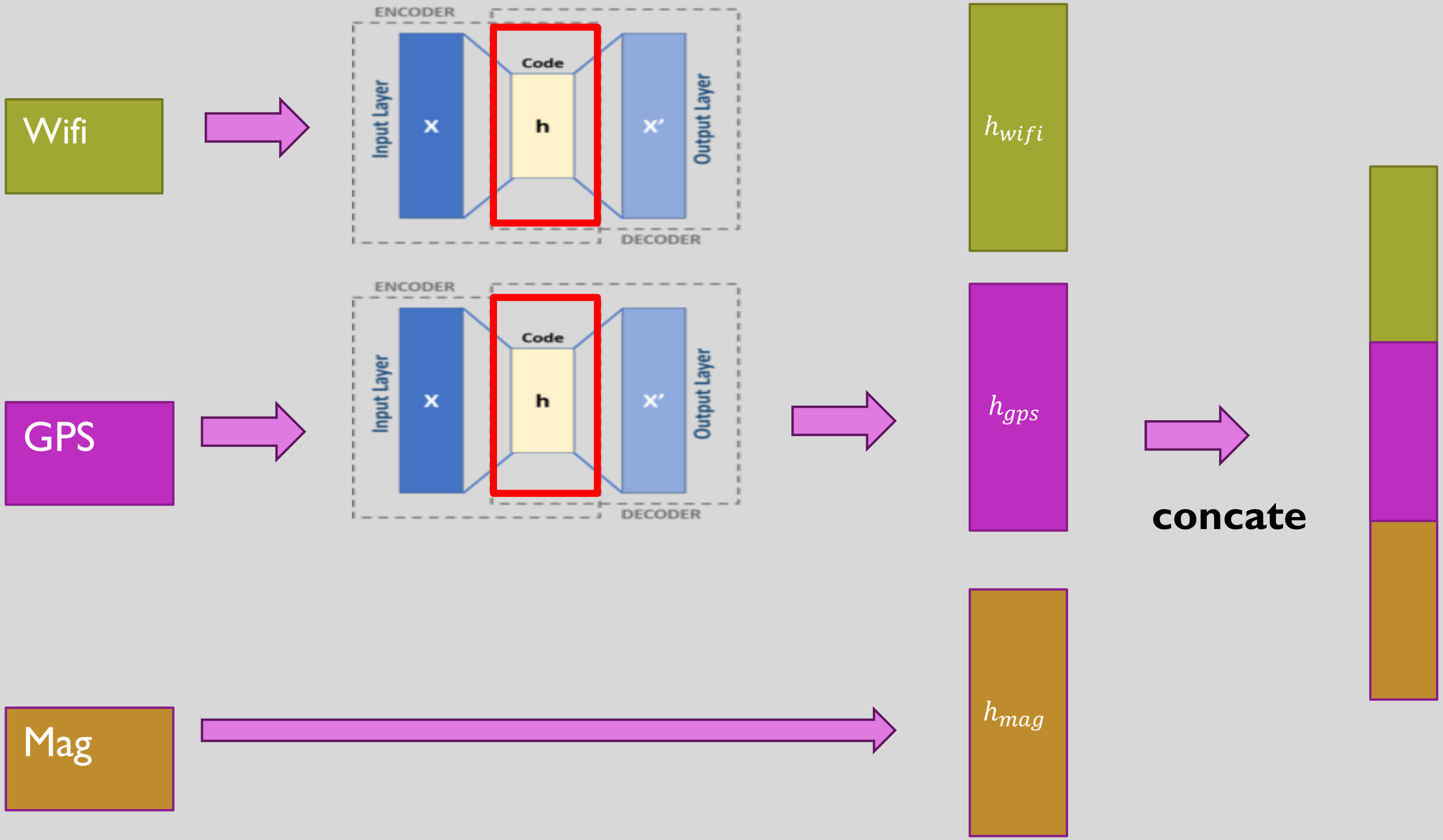
- Boundary = Indoor + Outdoor
- Multi-sensor
- Auto-encoder for feature extraction



Related Works for Localization by DL

- Construction of autoencoder combining LSTM
  - An integrated autoencoder-based hybrid CNN-LSTM model for COVID-19 severity prediction from lung ultrasound (Computers and Biology Medical 2021)
- Densenet autoencoder
  - The One Hundred Layers Tiramisu: Fully Convolutional DenseNets for Semantic Segmentation (CVPRW 2017)
- Multi-sensor I/O switching
  - Indoor/Outdoor Switching Detection Using Multisensor DenseNet and LSTM (IEEE Internet of Things Journal 2021)

Available Sensors around Boundaries



Wifi

GPS

Mag

h_{wifi}

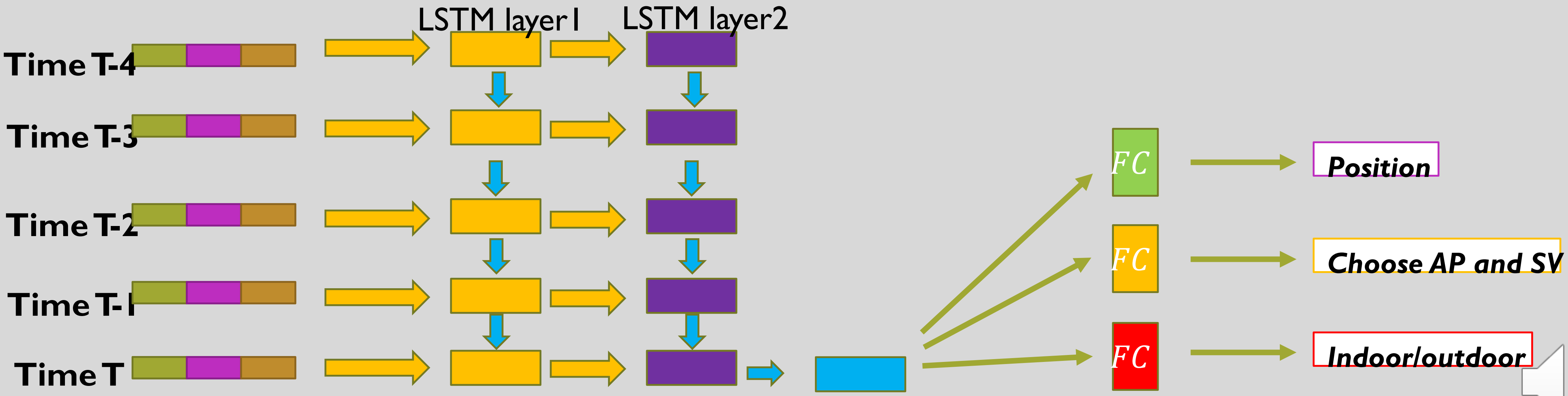
h_{gps}

h_{mag}

concate

Multiple Tasks Learning

- Which sensors to trust?
- What position?
- In indoor or outdoor?

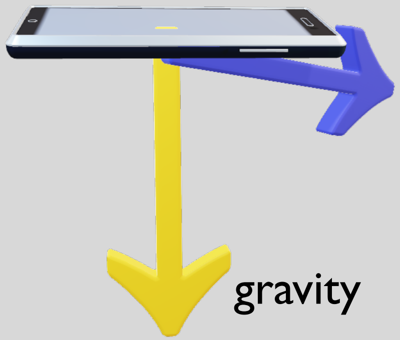


Research Steps

- Sensor data preprocessing
- Densenet autoencoder
- Route generator
- Multi task learning with Encoder combining LSTM

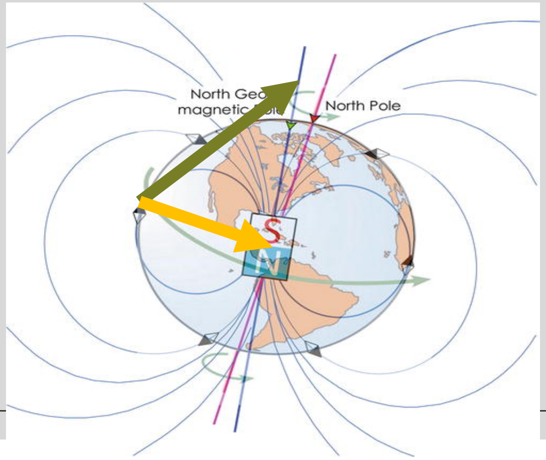
Sensor data preprocessing - Geomagnetic

- Regulate data to global geomagnetic field

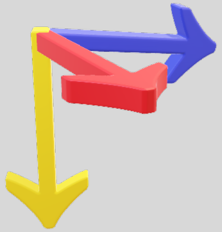


Geomagnetic field (South to North)

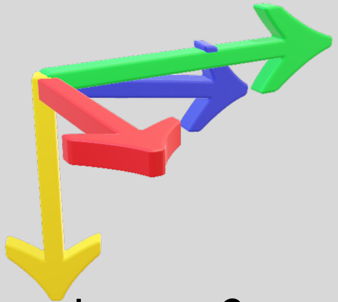
gravity



Step1:
gravity x geomagnetic field = vector1 (West to East)



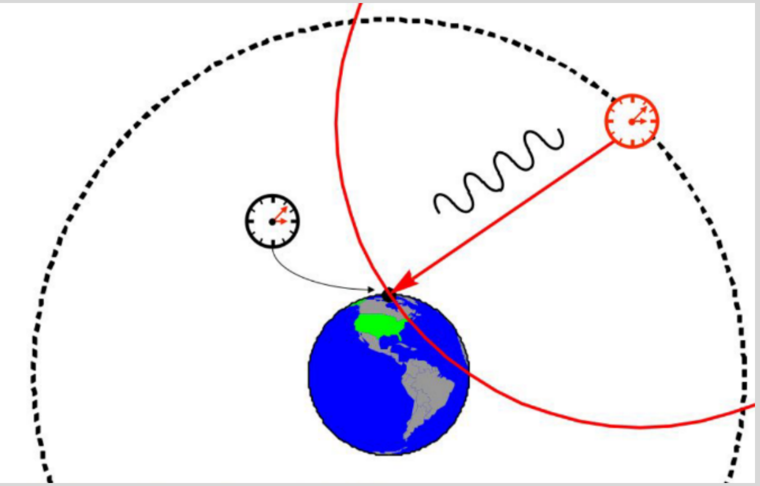
Step2:
vector1 x gravity = vector2



Step3:
With gravity, vector1 and vector2 we got an orthogonal matrix.
And we can project the geomagnetic field data we got in our phone
NED coordinates(North, East, Down) with the orthogonal matrix.

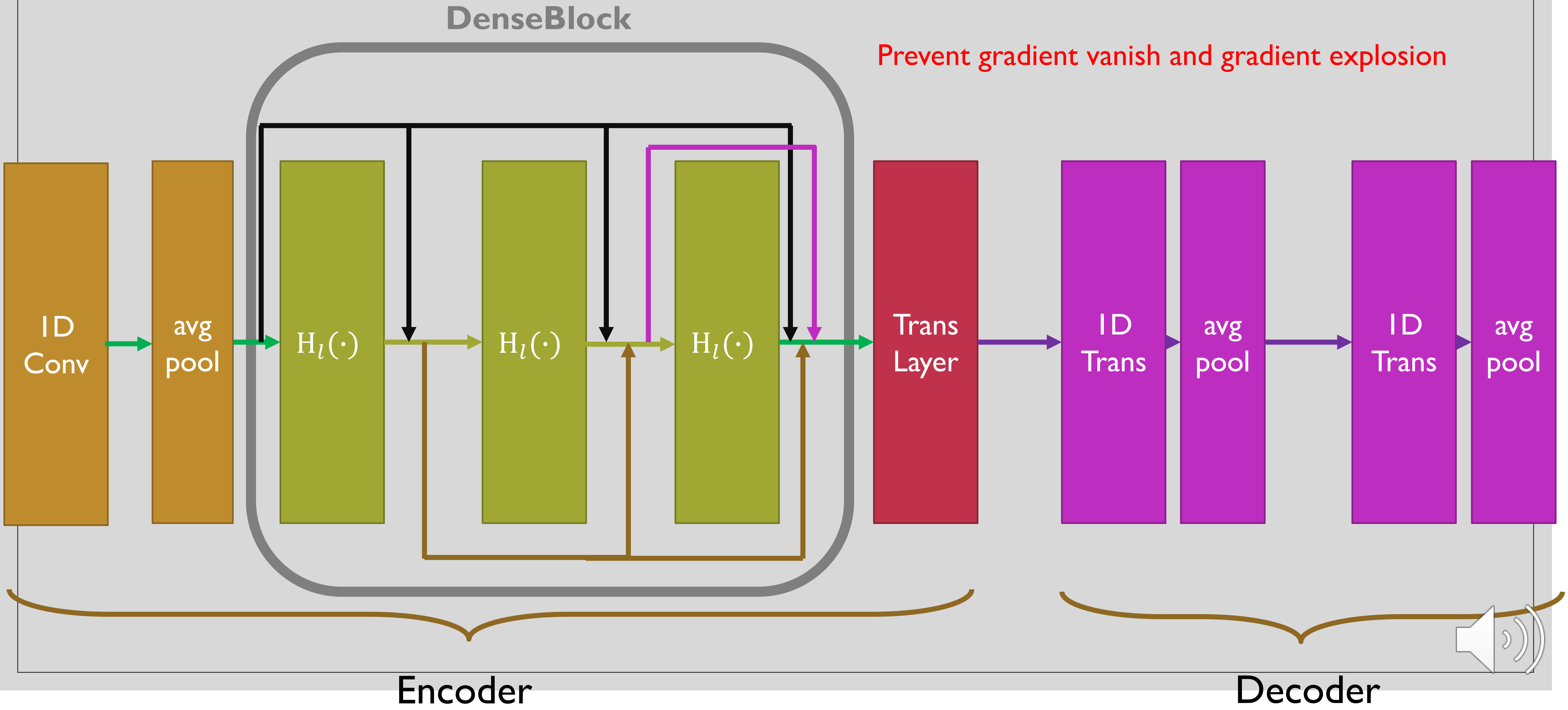
Sensor data preprocessing - GPS

- Get pseudorange and ephemeris (ECEF)
- ECEF to LLA



$$\underset{\text{time1}}{\begin{bmatrix} x_1 & y_1 & z_1 & PR_1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{10} & y_{10} & z_{10} & PR_{10} \end{bmatrix}} \underset{\text{time2}}{\begin{bmatrix} x_1 & y_1 & z_1 & PR_1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{10} & y_{10} & z_{10} & PR_{10} \end{bmatrix}} \dots$$

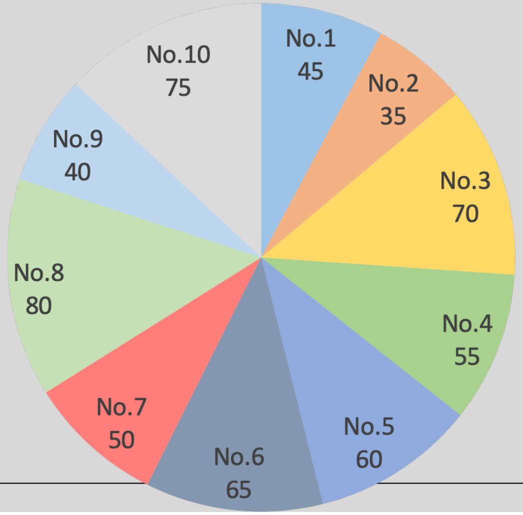
Densenet autoencoder



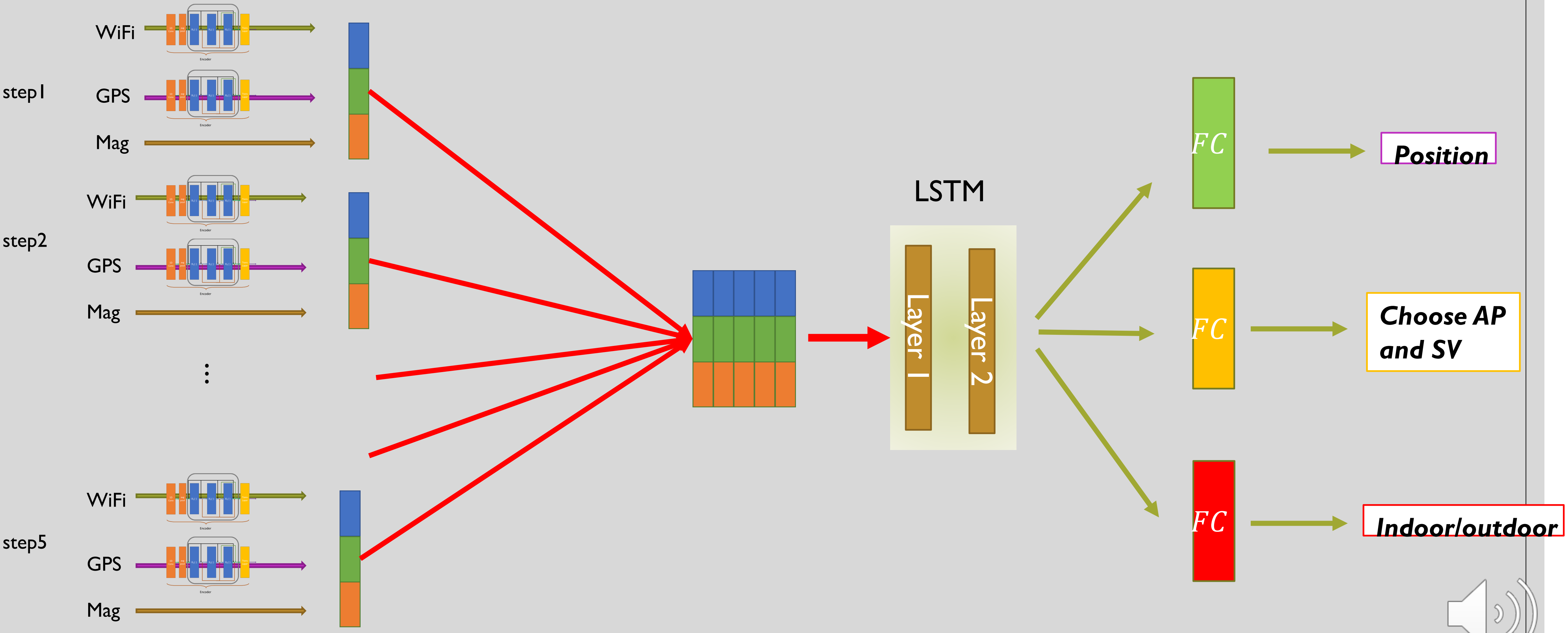
Prevent gradient vanish and gradient explosion

Route Generator

- $Pl_{iA} = \exp(-\frac{(x_i - x_p)^2 + (y_i - y_p)^2}{2\sigma^2})$
- $Pl_{im} = \exp(-\frac{(x_i + x_m - x_p)^2 + (y_i + y_m - y_p)^2}{2\sigma^2})$
- $Pl_i = \frac{Pl_{iA} + Pl_{im}}{2}$
- Pl_i *normalized, roulette wheel selection*

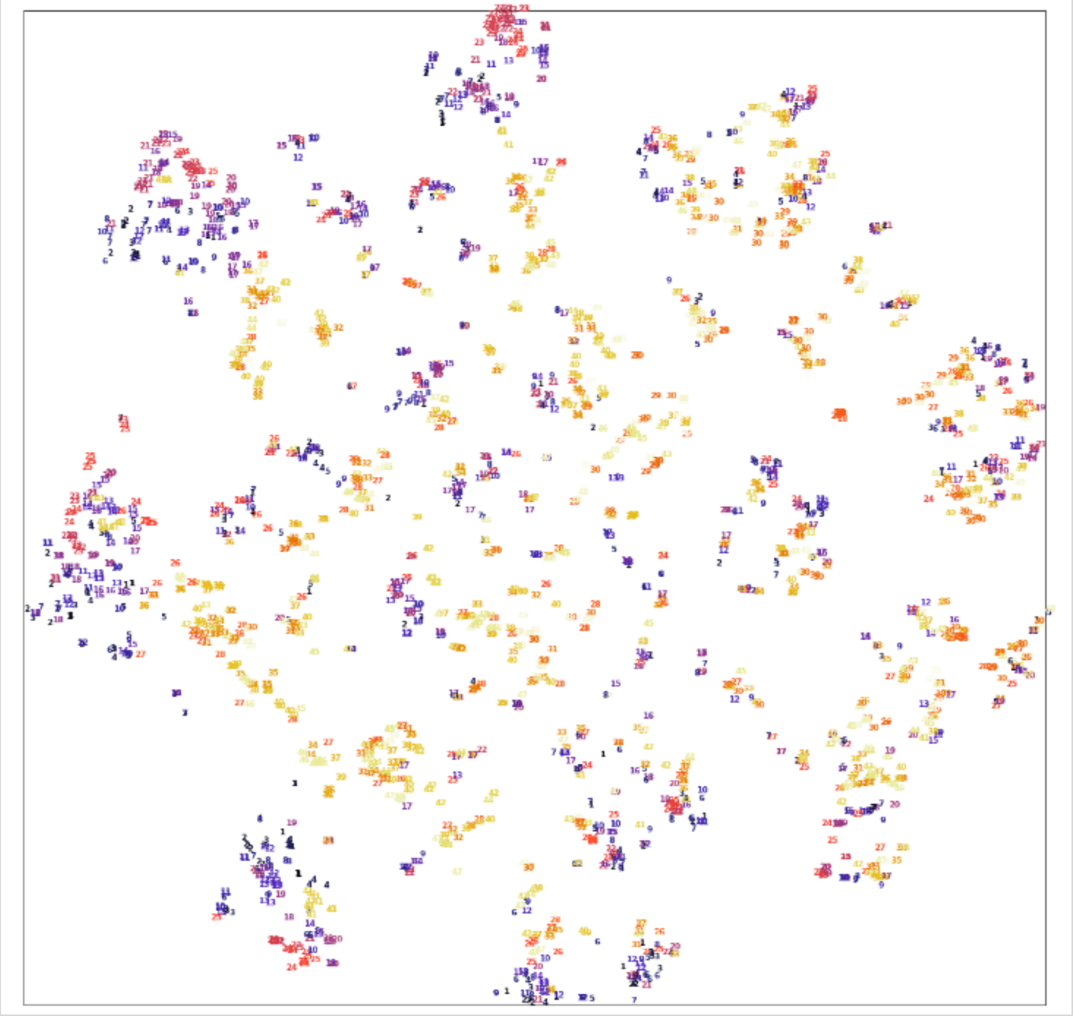


Multi task learning Encoder combining LSTM

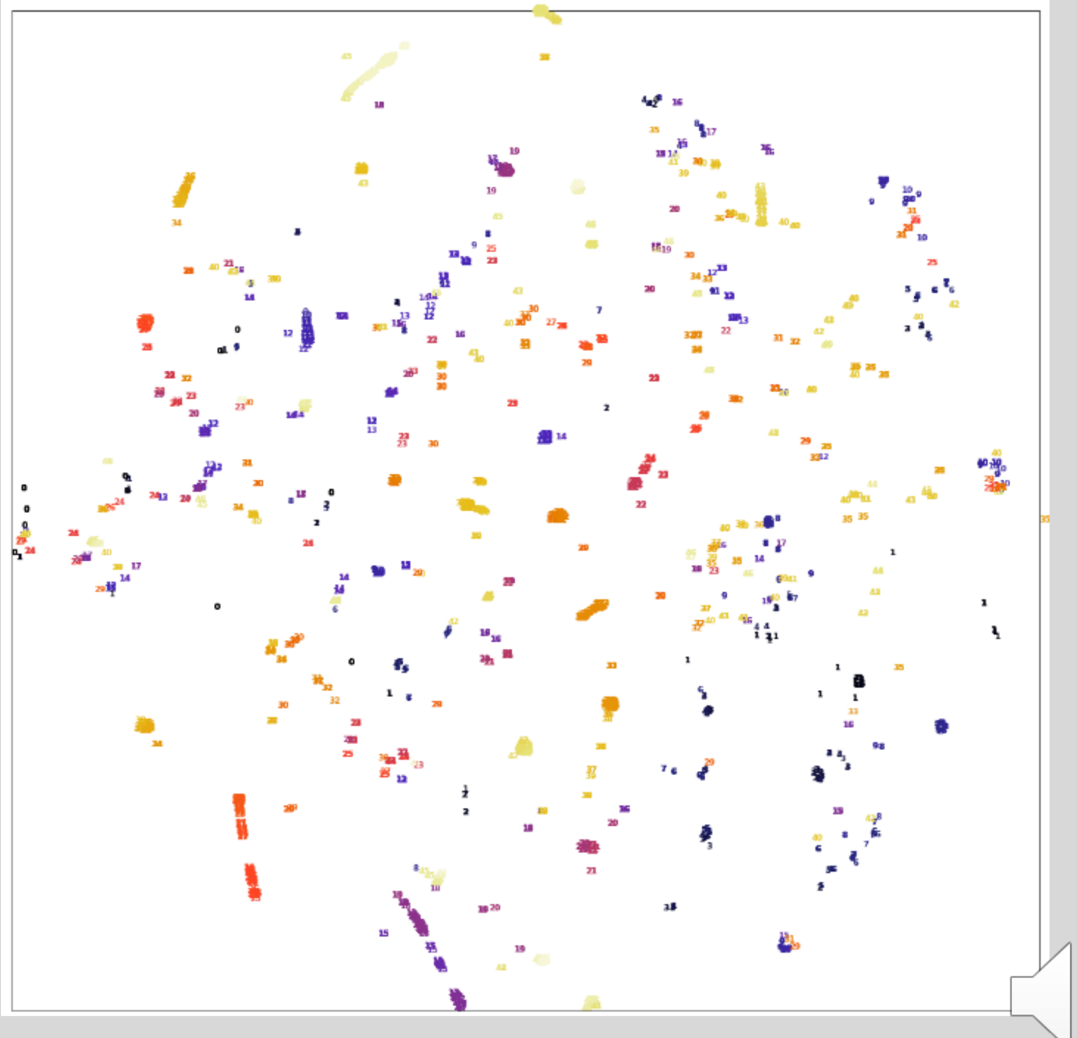


Multi task learning Encoder combining LSTM (Uniqueness of Latent Codes)

WiFi



GPS



Accuracy & Conclusions

- Multi-sensor for boundary separation
- Densenet autoencoder for LSTM prediction
- A new multi-task architecture

	output	AE + LSTM	LSTM	DenseAE + LSTM
Distance error	Predict location	0.761 m	0.415 m	0.052 m
	Predict coordination	-	1.06 m	0.16 m

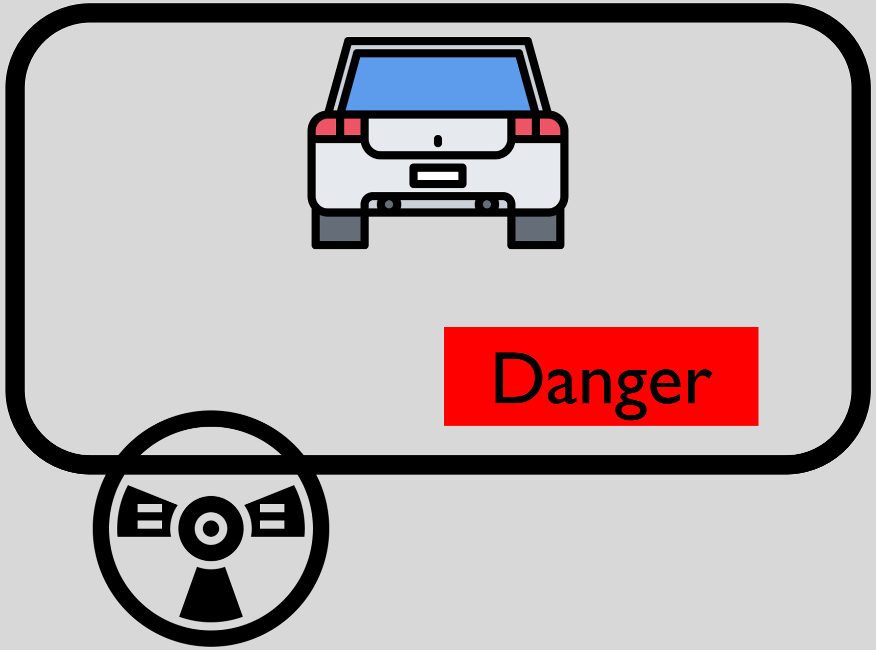
Part 2:

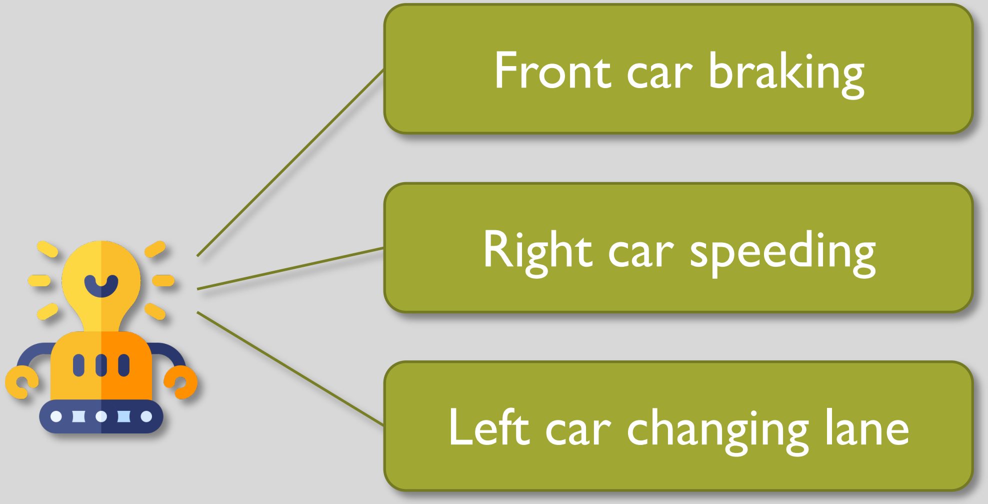
Computer Vision-Assisted Instant Alerts in 5G

Yu-Yun Tseng, Po-Min Hsu
Jen-Jee Chen, Yu-Chee Tseng

(appeared in ICCCN 2020)

A Safe Ride Needs Lots of Surrounding Info





Front car braking

Right car speeding

Left car changing lane

Requirements: Instant & Accurate
(no irrelevant alerts)

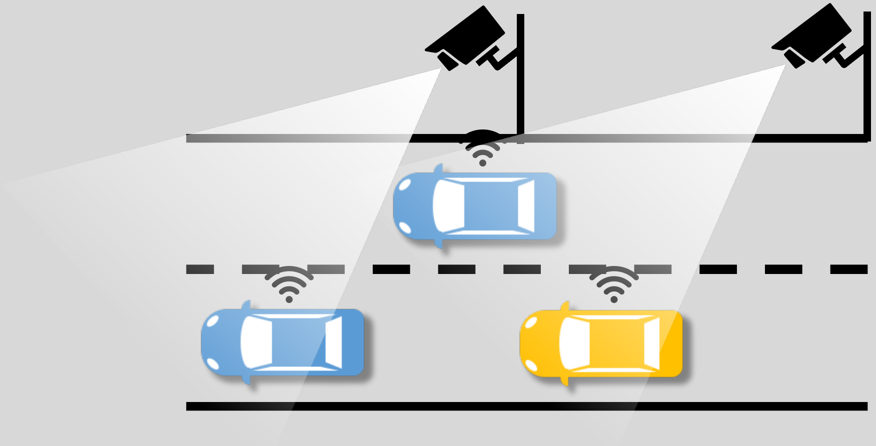
Concept: Instant Alerts

5G Vehicle-to-Everything (V2X)

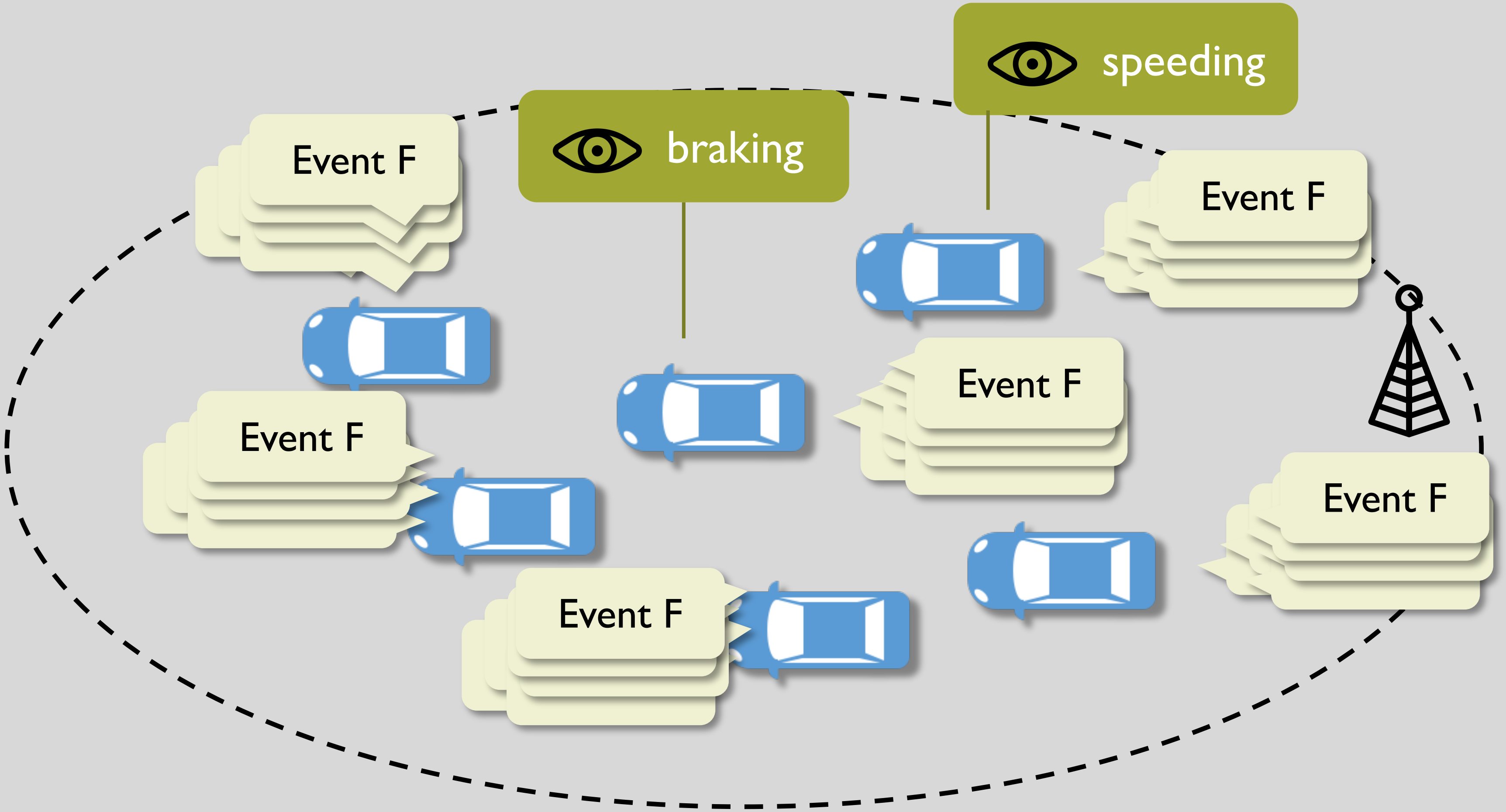
- Cooperative Awareness Messages (CAMs): periodical heartbeats
- Decentralized Environmental Notification Messages (DENMs)

[30] 3GPP TS 22.185, "Service requirements for V2X services," Jul. 2018
[31] 3GPP TR 22.885, "Study on LTE support for Vehicle to Everything (V2X) services," Dec. 2015

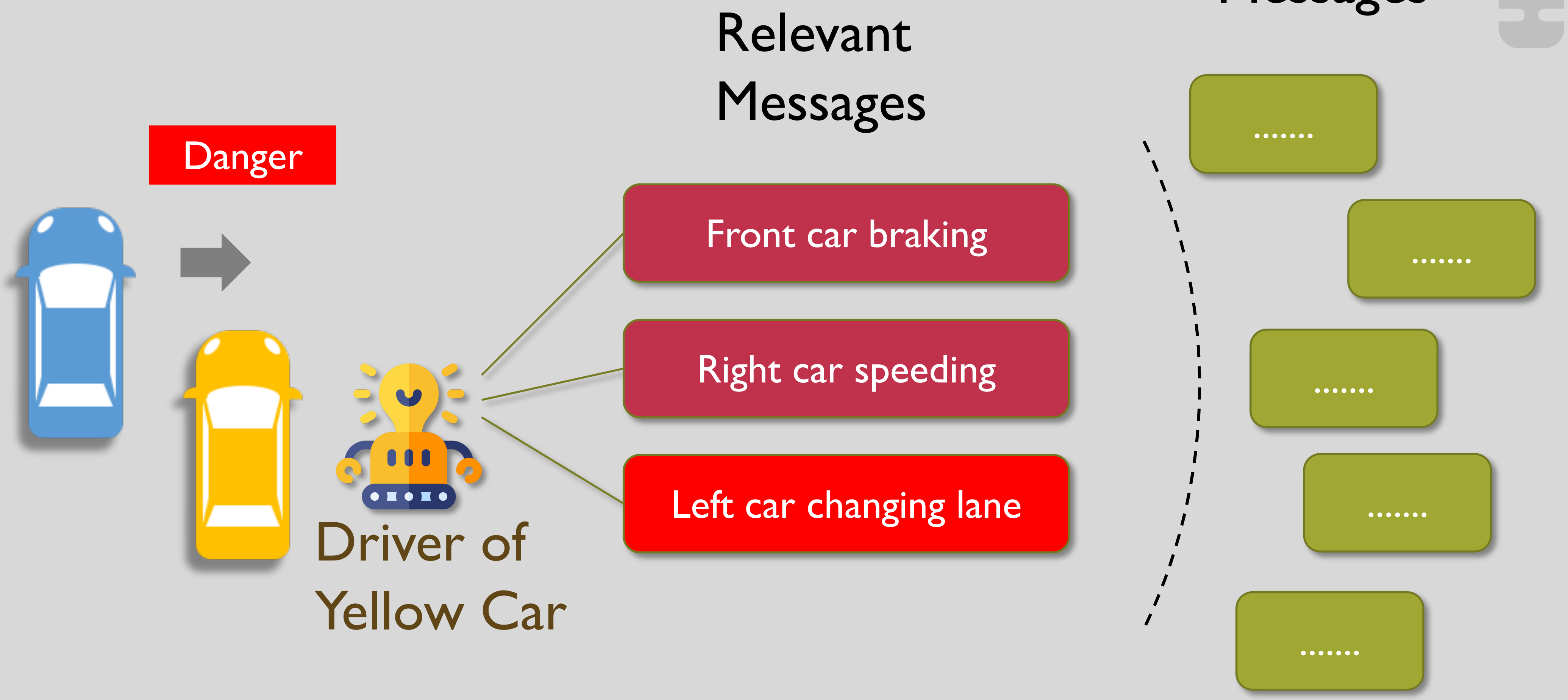
- On-board sensors
- Road-side cameras



“Broadcasting Storm” in Alerting



Accurate Alerting



Relevant Messages

Irrelevant Messages

Danger

Driver of Yellow Car

- Front car braking
- Right car speeding
- Left car changing lane

…….

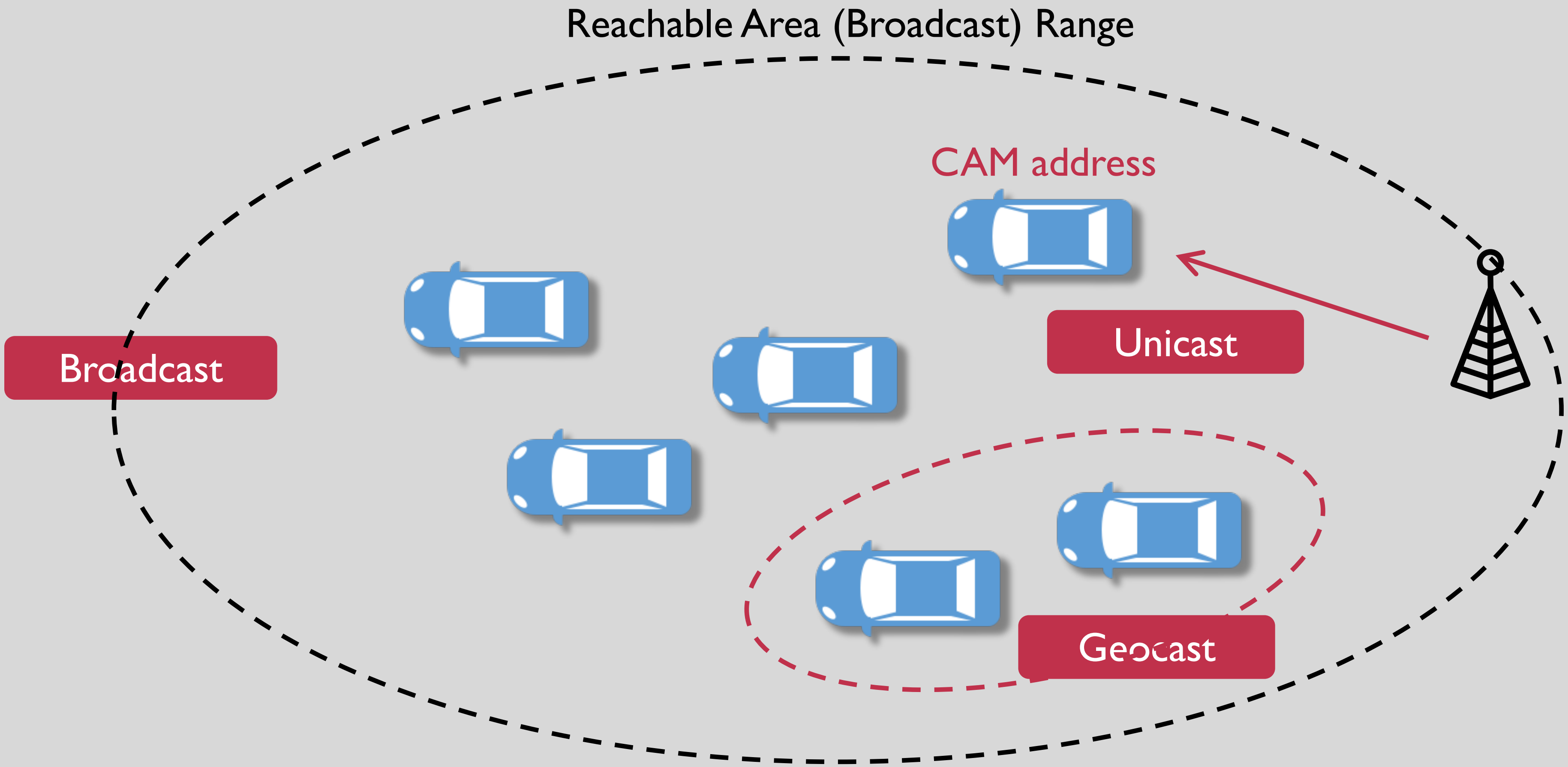
…….

…….

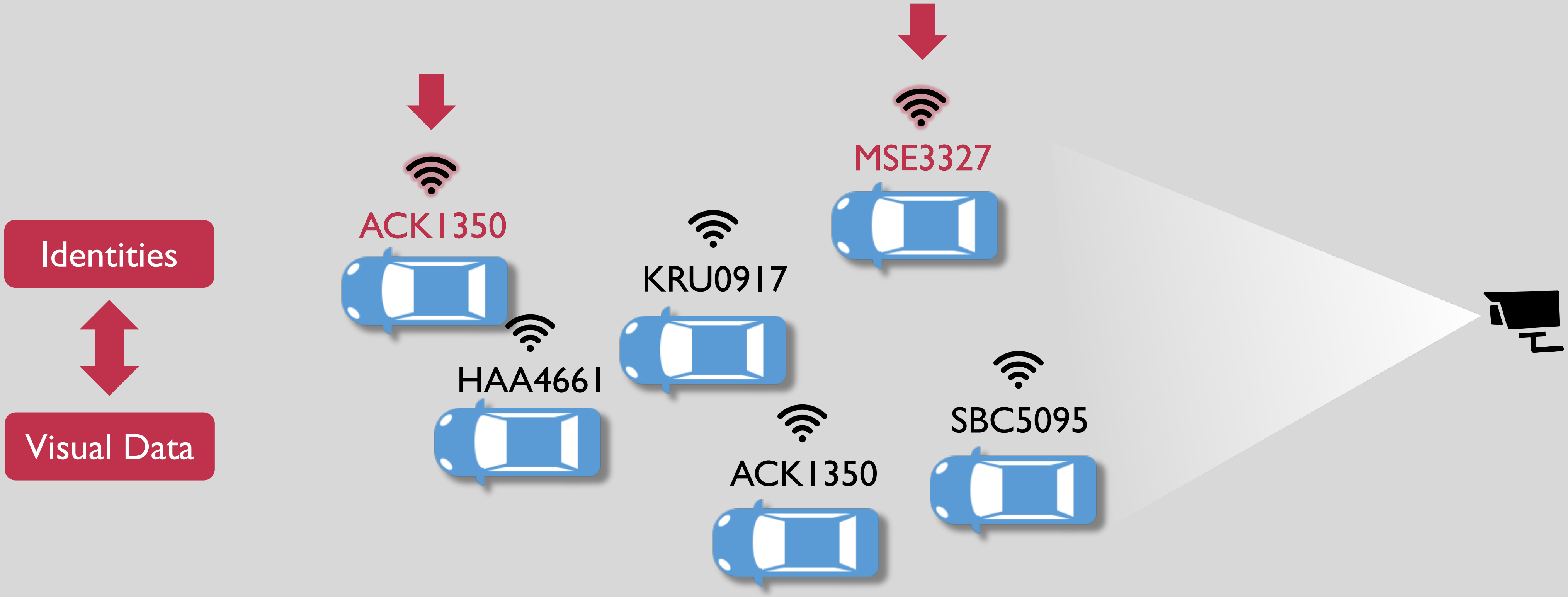
…….

…….

Alerting Ranges



How can computer vision help?
“Vehicle Identification”

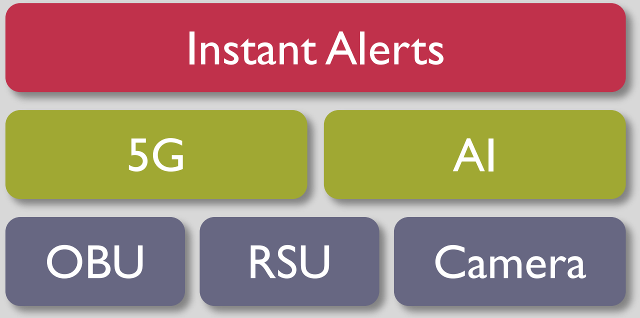

Identities

Visual Data

Vehicle Identification by matching visual and radio packets

Embedding Computer Vision in 5G

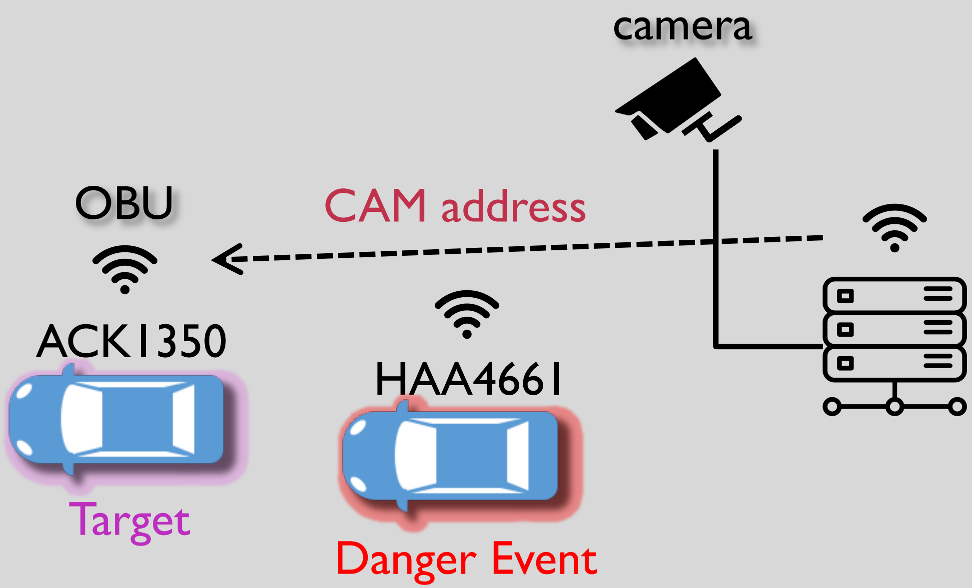
- Vehicle identification
- Detect danger events
- Recognize alerting targets
- Send alerts by unicast



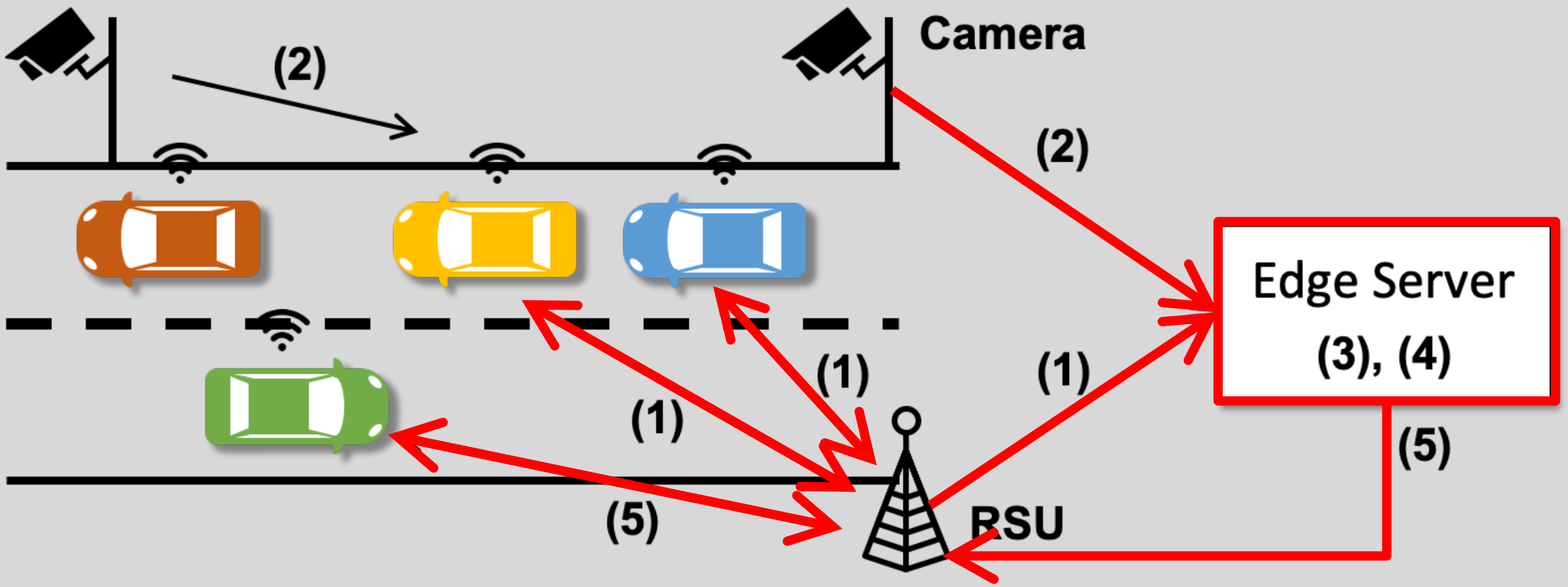
Instant Alerts

5G AI

OBU RSU Camera



System Architecture



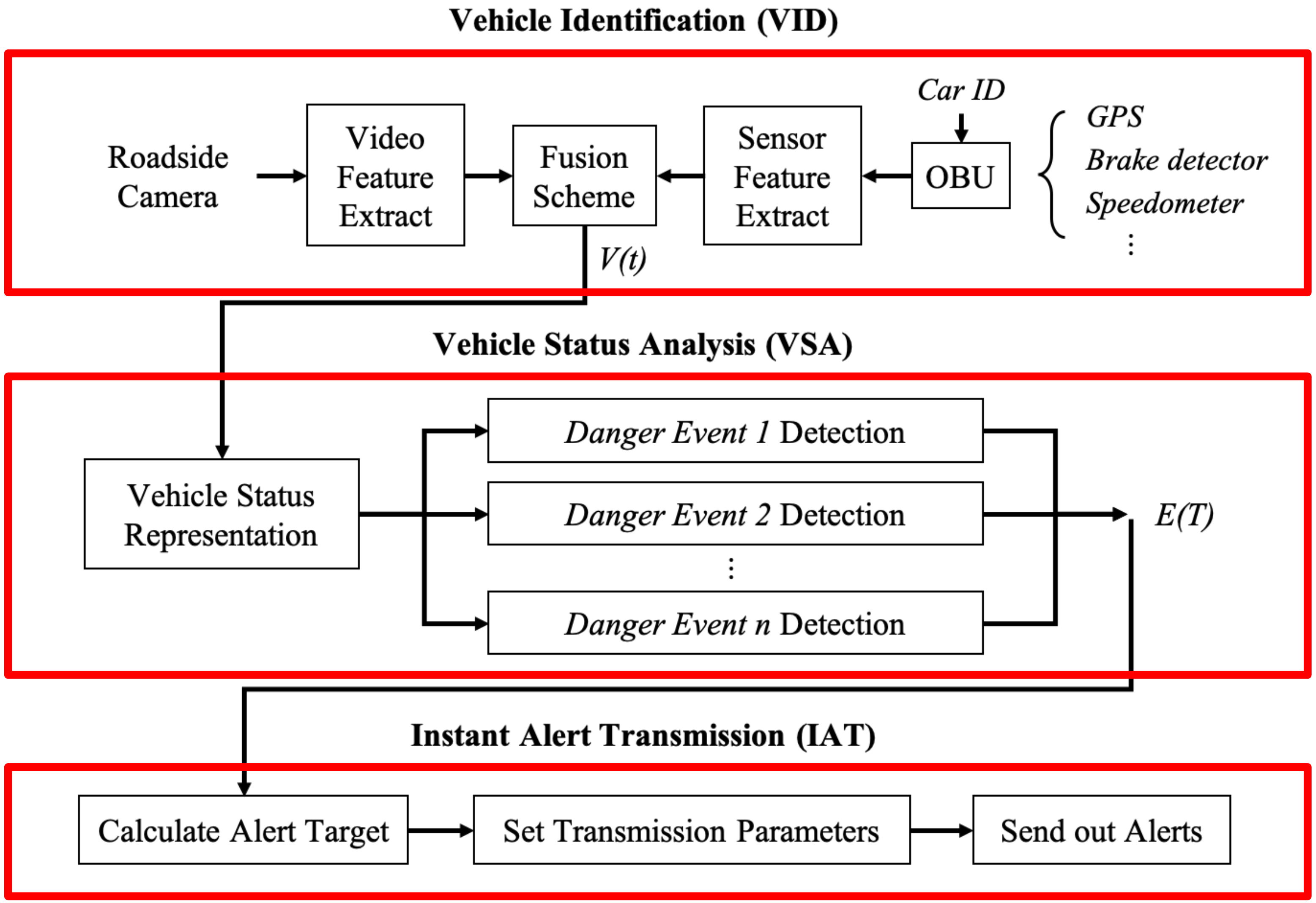
(1) OBU data. (2) Video data. (3) Vehicle Identification. (4) Danger detection. (5) Instant alert.

CV-Assisted Alert Model

Vehicle Identification (VID)

Vehicle Status Analysis (VSA)

Instant Alert Transmission (IAT)



Vehicle Identification (VID)

Roadside Camera → Video Feature Extract → Fusion Scheme ← Sensor Feature Extract ← OBU

Car ID → OBU

GPS, *Brake detector*, *Speedometer*, ⋮ → OBU

Fusion Scheme → *V(t)*

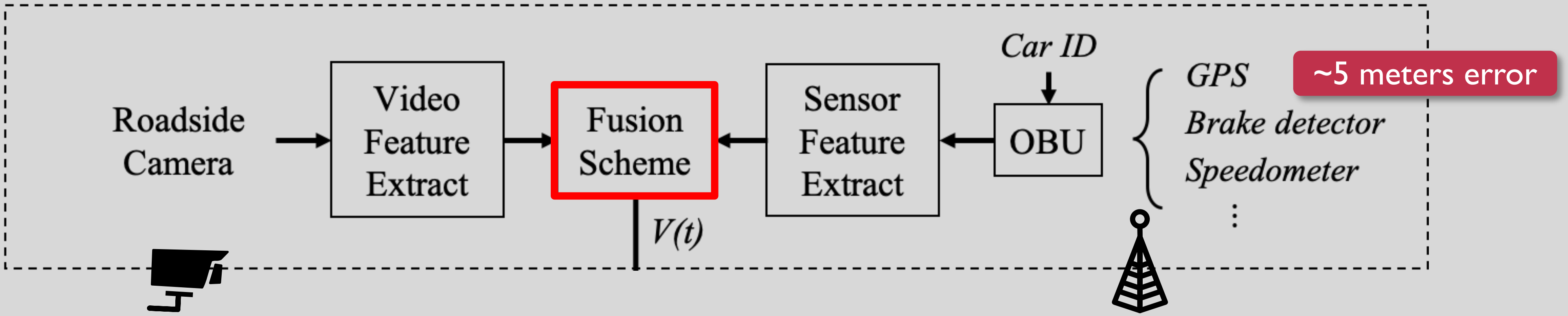
Vehicle Status Analysis (VSA)

Vehicle Status Representation → *Danger Event 1* Detection, *Danger Event 2* Detection, ⋮, *Danger Event n* Detection → *E(T)*

Instant Alert Transmission (IAT)

Calculate Alert Target → Set Transmission Parameters → Send out Alerts

Vehicle Identification

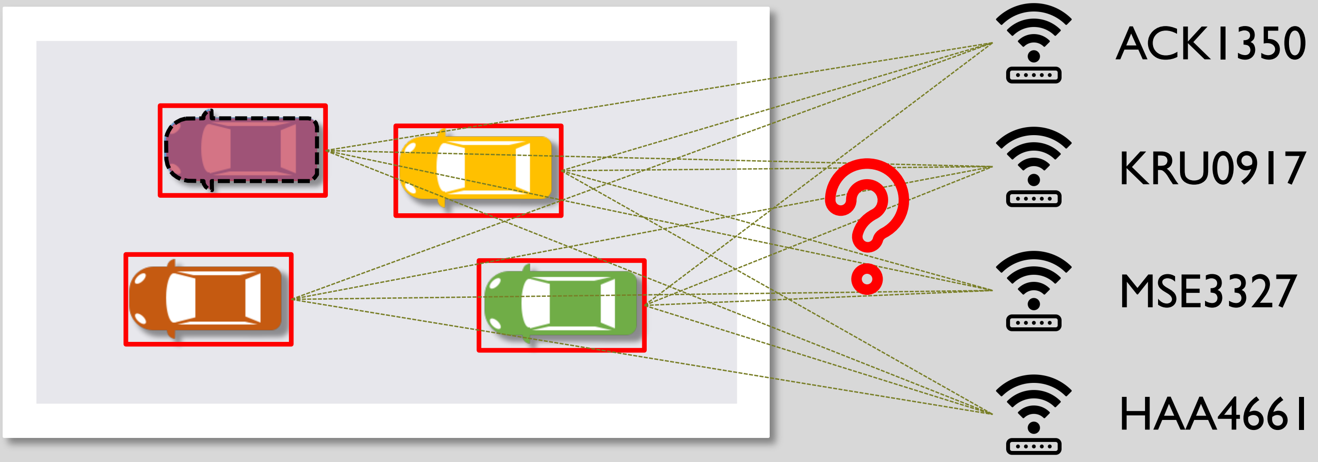


Neural Network Object Detection

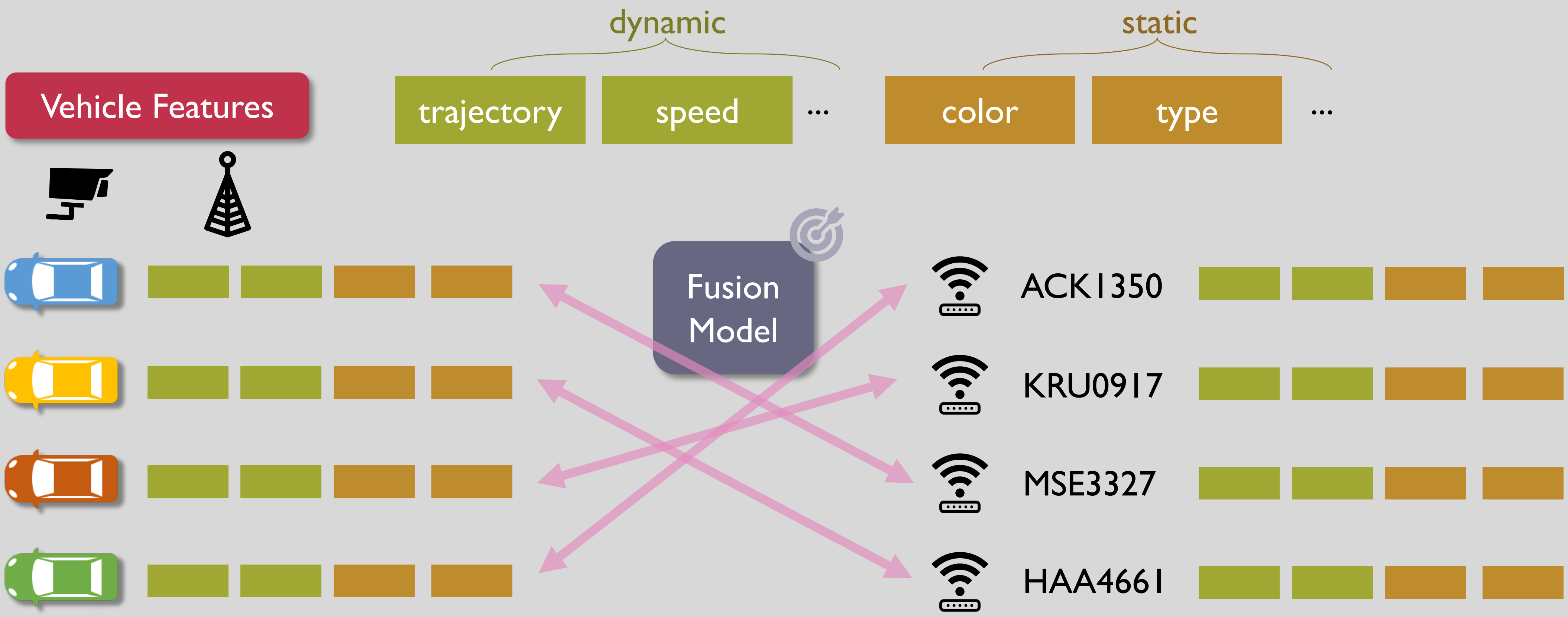
bounding box

or

mask



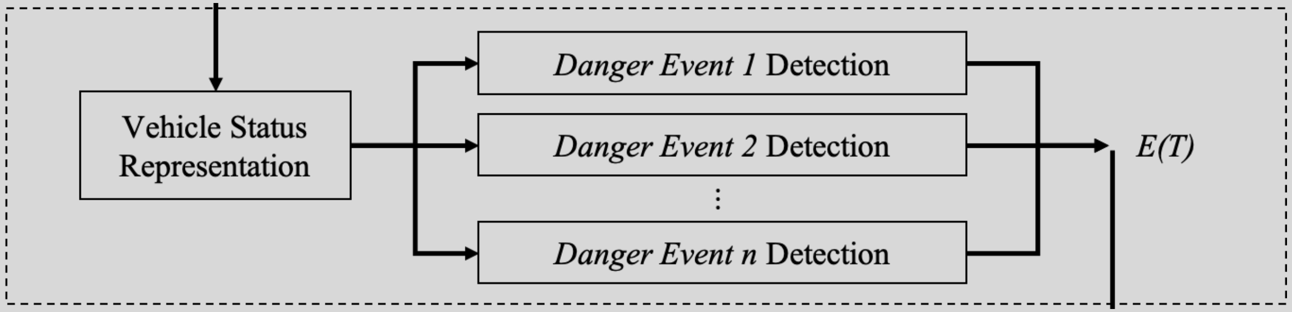
Fusion Scheme



[1] T.-K. Lee et al. "Augmenting Car Surrounding Information by Inter-Vehicle Data Fusion," WCNC, 2019

VID — VSA — IAT

Vehicle Status Analysis：
Danger Event Detection


Vehicle Status Representation

Danger Event 1 Detection

Danger Event 2 Detection

⋮

Danger Event n Detection

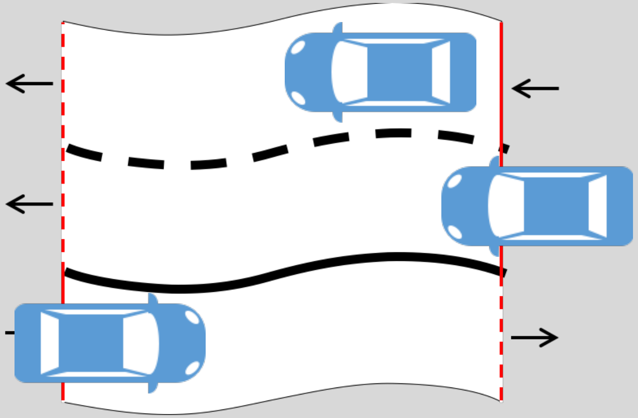
E(T)

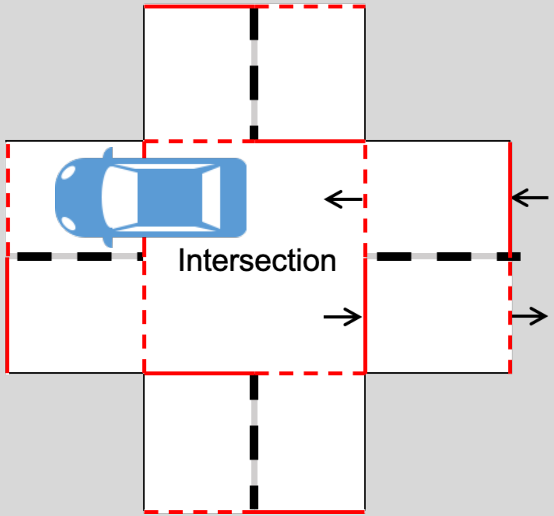
Sudden Brake
- acceleration
- speedometer

Sudden Lane Change
- trajectory
- velocity
- video
- speedometer

Overtaking at Curve
- trajectory
- video

Fast Intersection Entrance
- trajectory
- velocity
- video
- speedometer



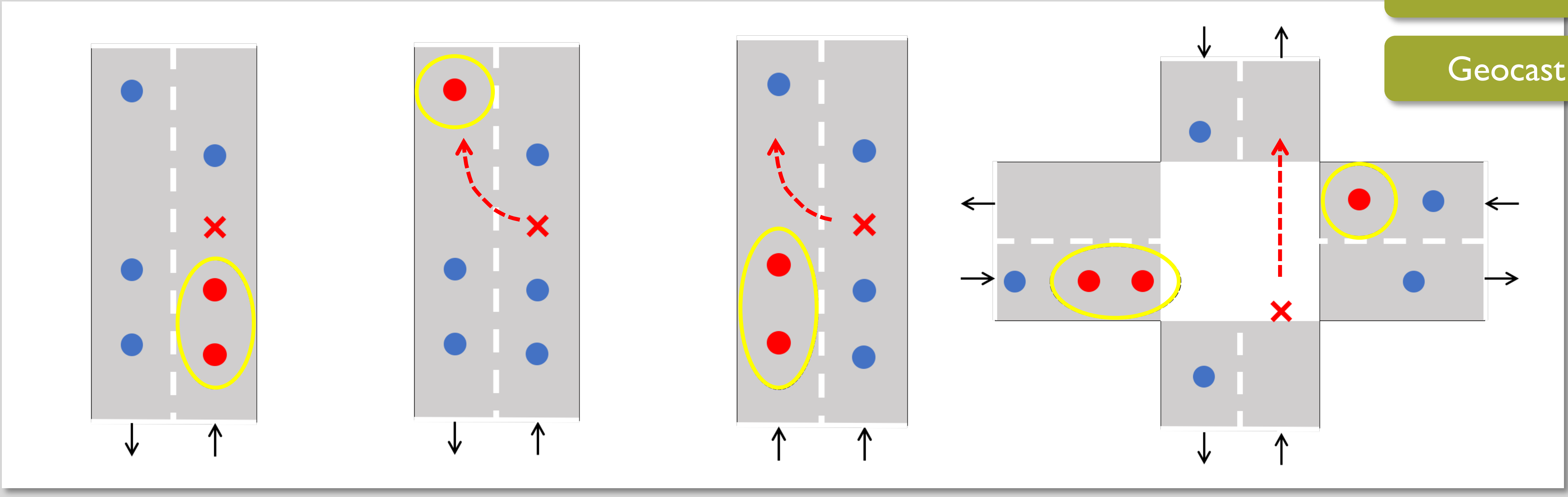


VID — VSA — IAT

Instant Alert Transmission

Unicast

Geocast



Sudden Brake

Overtaking at Curve

Sudden Lane Change

Fast Intersection Entrance

Transmission Parameters Analysis

$$Q \leq 1 - P_{fail}^{n_{rep}} \quad (1)$$

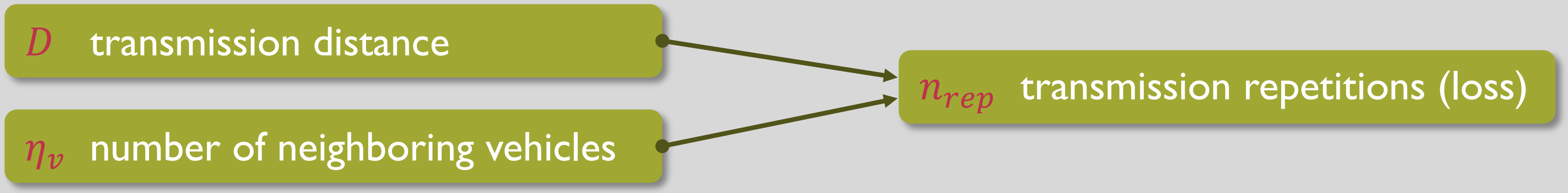
$$SINR \rightarrow MCS \rightarrow BER \rightarrow P_{fail} \rightarrow n_{rep}$$

$$SINR = 10 \log \frac{S_{tx} - (128.1 + 37.6 \log D)}{\eta_v P_{CAM} P_{crash} S_{CAM} + N} \quad (2)$$

Q: the reliability of successful delivery
P_{fail}: probability that a vehicle in G misses
n_{rep}: number of repetitions of alert transmission

$SINR$: Signal-to-Inference-plus-Noise ratio
MCS: Modulation and Coding Scheme

D: transmission distance
η_v: number of neighboring vehicles

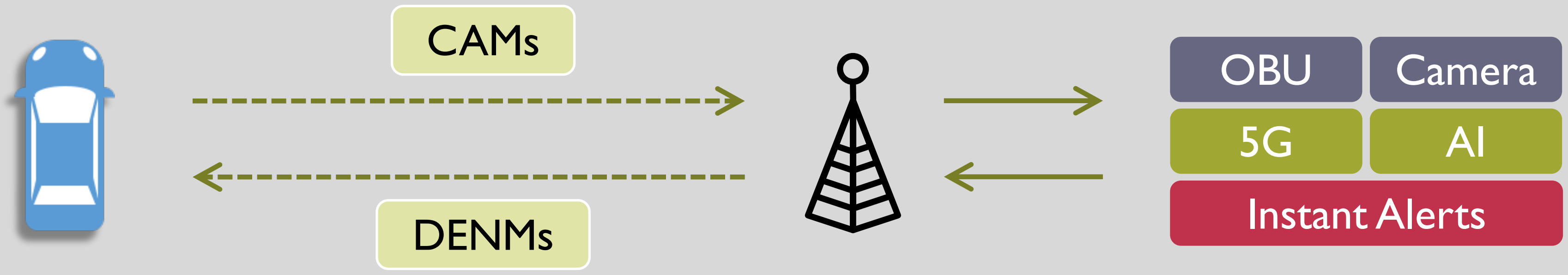


D transmission distance

η_v number of neighboring vehicles

n_{rep} transmission repetitions (loss)

Conclusions



CAMs

DENMs

OBU

Camera

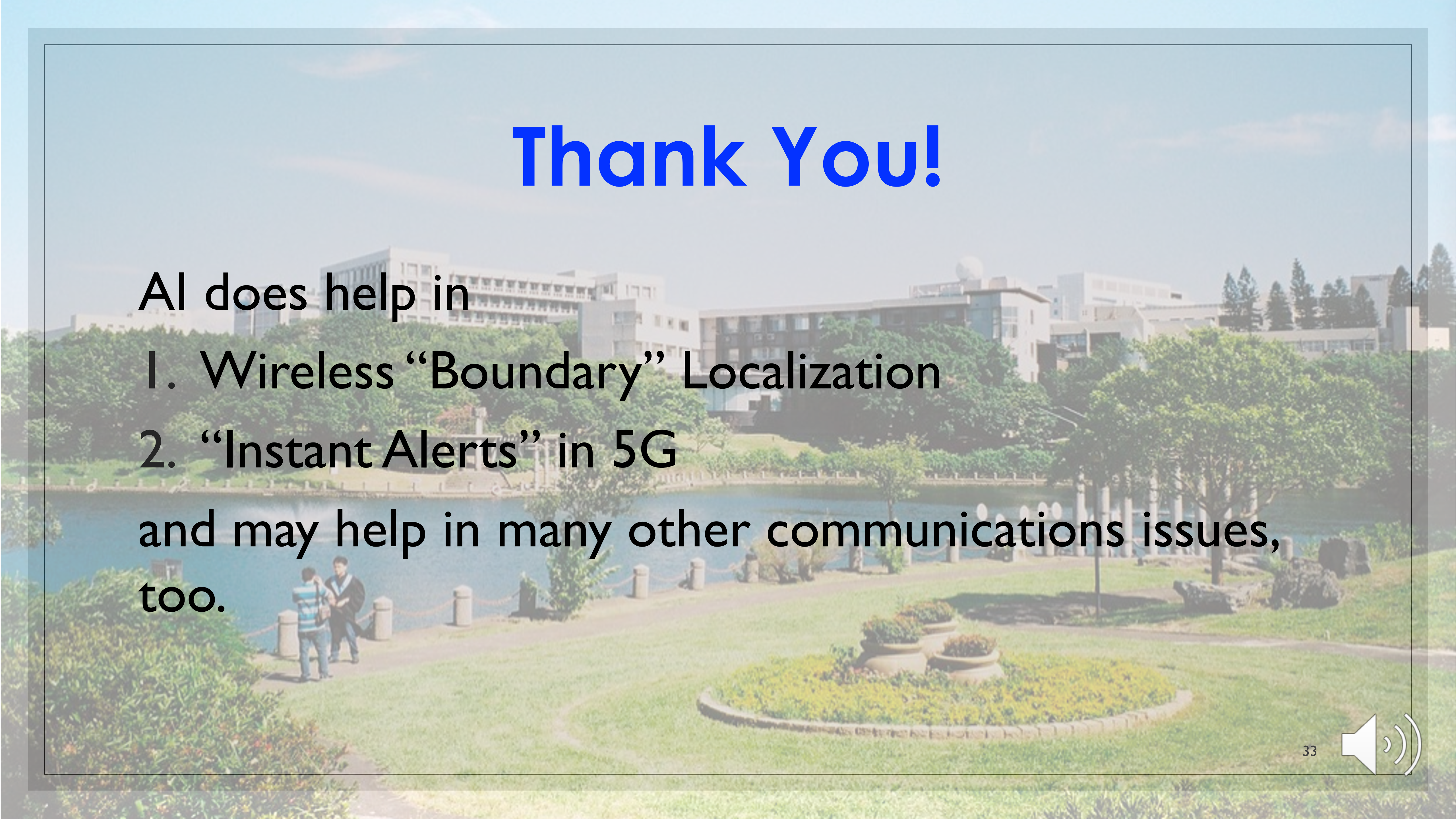
5G

AI

Instant Alerts

Road Safety = 5G V2X + Computer Vision

Global Sensing = On-Board Sensors + Road-Side Cameras



Thank You!

AI does help in

1. Wireless "Boundary" Localization
2. "Instant Alerts" in 5G

and may help in many other communications issues, too.